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# External referencing and pharmaceutical price negotiation<sup>\*</sup>

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## Abstract

External referencing (ER) imposes a price cap for pharmaceuticals based on prices of identical products in foreign countries. Suppose a foreign country (F) negotiates prices with a pharmaceutical firm while a home country (H) can either negotiate independently or implement ER based on the foreign price. We show that country H always prefers ER if (i) it can condition ER on the drug being subsidized in the foreign country and (ii) copayments are higher in H than in F. H's preference is reinforced when the difference between country copayments is large and/or H's population is small. External referencing by H always harms F if (ii) holds, but less so if (i) holds.

*Keywords:* Pharmaceuticals, external referencing, price negotiation.

*JEL codes:* L65, I18.

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## 1. Introduction

This paper aims at analyzing the incentives for a country to engage in external referencing for pharmaceuticals as opposed to directly negotiating the drug's price with the firm. External referencing (ER) consists of a price cap for pharmaceuticals, based on prices of identical products in other countries.

With very few exceptions, most countries in the industrialized world have implemented ER at some point of time. Indeed, the policy is commonly used by most European countries, where it is also usual that prices be determined by negotiations between government agencies and pharmaceutical firms.<sup>1</sup> For instance, ER came into force in the Netherlands and in Switzerland in 1996, under the Pharmaceutical Prices Act and the Health Insurance Law, respectively. In the Netherlands, the maximum price for a drug is established as an average of the prices of the drug in Germany, France, UK, and Belgium. Prior to 1996, the prices for pharmaceuticals in the Netherlands were not subject to any regulation and they were high compared to the prices in those surrounding countries. As expected, the Pharmaceutical Prices Act resulted in considerably lower prices in general for the Netherlands (see Windmeijer *et al.*, 2006). In Switzerland, the Health Insurance Law introduced a 'positive list' of reimbursed pharmaceuticals. For a drug to be included in this positive list, its price should not exceed the average of the prices in Germany, Denmark, the Netherlands and the UK.

Both the Dutch and the Swiss experiences raise the following questions: Why are these countries interested in engaging in ER rather than in any other type of cost-containment regulation? Namely, given that pharmaceutical prices are directly negotiated upon in the UK for example, why does the Dutch health authority rely on these foreign prices rather than on prices specifically negotiated for the Netherlands? What is the influence of the ER policy on the reference countries?

To tackle these questions, we use a model where a pharmaceutical firm (simply “the firm” henceforth) sells a drug in two countries. To focus on the role of consumer copayments and also to gather whether any country size effects exist we assume that

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<sup>1</sup> See Section 2 for a detailed account of the European experience.

countries differ both in size (namely, the number of consumers) and in the level of copayments.

In our main contribution we assume that, in the absence of an ER policy, both countries negotiate the price with the firm and are unable to threaten the firm with not authorizing the drug for sale in case of negotiation failure. The only threat available to countries is that of not listing the drug for reimbursement, so that the firm can still sell the drug at any price of their choice, but with no subsidy. This assumption is motivated by the fact that in Europe negotiating agencies have no role in the authorization of the drug. We therefore say that in Europe we are in a “weak threats” scenario. Considering such a scenario, we analyze how the commitment by a country to engage in ER affects negotiations in a foreign reference country and ultimately determines the firm’s total profit.

Our results with independent negotiations in each country are a direct corollary of Jelovac (2003), where she shows that with independent negotiations, prices are lower where subsidies are higher.<sup>2</sup> Since a more generous subsidy results in a smaller negotiated price, there is scope for a country to engage in ER if its copayments are larger than the other’s. Hence, our contribution is the characterization of the effect of ER in this setting. To set some terminology, we refer to the country that would have an incentive to engage in ER as the “home” country. We refer to the country whose price serves as reference for the ER policy as “foreign country”.

We show that the effects of an ER policy crucially depend on its specific design. In this respect, we distinguish between non-conditional and conditional ER policies. In a non-conditional ER policy, the price in the foreign country is used as a price cap regardless of whether it was the result of successful negotiations in the foreign country or chosen by the firm once negotiations had failed. In contrast, under a conditional ER policy, the foreign price is used as a price cap only if it is the result of successful negotiations, i.e., only if the drug is included in the foreign country’s list of subsidized drugs.

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<sup>2</sup> This may seem counterintuitive, since in markets that use the price mechanism as an allocation device high subsidies are associated with demand inelasticity and high prices. However, with bargaining, high subsidies increase the gains from negotiation to firms, who are then willing to bear lower prices.

The main results of the paper are the following. First, an unconditional ER policy harms both countries and should never be implemented. The reason is that the firm will find it optimal to force a very high foreign price even if this forces negotiation failure in the foreign country. Let us now consider conditional ER. Our second result is that, with weak threats, an ER policy increases the negotiated foreign price. This harms the foreign country. Yet, the home country prefers conditional ER to an independent price negotiation. However, this preference diminishes as the relative population size grows in the home country, although it never disappears. Finally, as compared to the profits resulting from independent price negotiations, ER brings an increase in profits in the foreign country and a decrease in the home country. Moreover, the second effect is strong enough so that overall profits decrease.

We also consider two extensions of our model to check the robustness of our results. First, suppose that health agencies are able to threaten with a ban on the drug. That is, agencies are able to condition drug authorization on negotiation success. We refer to this as the “tough-threats” scenario. We show that our main insight - the home country is benefited while the firm is harmed by conditional ER – still holds. However, in contrast to the weak threats scenario, ER does not harm the foreign country as the negotiated price in the foreign country is unaffected by the home country’s ER.

Returning to the weak threats scenario, the second extension considers the possibility that the firm offers a transfer to the foreign country in exchange for a high price. We show that, if these transfers are observable to the home country and if the agency in the home country can ex-ante threaten to delist the drug upon this observation then the firm will never find it profitable to engage in such transfers.

Let us offer some intuition for our main results. Under weak threats, we find that the ER policy worsens the bargaining power of the foreign country *vis à vis* the firm, thereby increasing the foreign price. The mechanism is as follows. The firm’s threat point in the bargaining with the foreign agency improves when an ER policy is implemented. By how much depends on the way the home country designs its ER policy. As an illustration, consider the extreme case where the ER is un-conditional. As explained above, the firm can exploit the home country’s promise that it will “copy” the foreign price no matter what. Namely, the firm lets negotiations in the foreign country break down by demanding a very high price, in order to maximize the

profits accrued in the home country, where demand is inelastic due to the subsidy. This effect is also present (although in a smaller scale) under conditional ER with weak threats. Indeed, the only situation where the effect does not exist is in the tough-threats scenario. In this scenario, a negotiation failure in the foreign country implies that the firm loses home country's market altogether.

Let us return to the possibility that the firm is able to make transfers to the foreign agency in exchange for higher prices. Here, results depend on whether transfers are observable to the home agency. If they are not, then the situation is equivalent to an *unconditional* ER. Namely, the firm can induce a large price in both countries. The only difference with unconditional ER is that the foreign agency is not forced now to delist the pharmaceutical drug. In contrast, if transfers are observable (and the home country has strong incentives to monitor), the home country can commit ex-ante to delist the drug upon observation of such transfers. This is consistent with the weak threats assumption: under a conditional ER, the drug is delisted in the home country upon observation of a negotiation failure in the foreign country. As advanced above, the threat of delisting is enough to discourage such transfers from the firm. We have no systematic information on how referencing countries respond to transfers of this kind. We do however observe them. For instance, Pfizer offered disease management services to state residents in the state of Florida in order to avoid a low price that would be a benchmark for other states.<sup>3</sup>

Another contribution of our paper is that it enlightens (i) the connections between ER and parallel imports (PI), and (ii) the connections between ER and most favored nation (MFN) clauses.<sup>4</sup> As for (i), the closest paper to ours is Pecorino (2002), who studies the effects of parallel imports from the foreign to the home country.<sup>5</sup> He obtains that, surprisingly, the presence of PI results in higher profits for the firm. It turns out that our model with unconditional ER yields the same result, as it constitutes a different version of Pecorino's, namely one with subsidies (which he assumes

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<sup>3</sup> "Florida-Pfizer deal charts new territory in overall cost control, but can it work?" *Formulary* September 1, 2001. We thank the Editor for suggesting this real-world case.

<sup>4</sup> We thank a referee for pointing this connection to us.

<sup>5</sup> Notice the parallelism in our terminology here: the country engaging in PI/ER is referred to as the home country.

away).<sup>6</sup> Hence the statement made by Danzon *et al.* (1997) that ER is tantamount to a 100% parallel import is confirmed for the case of an unconditional ER policy. In contrast, if ER is conditional, Pecorino's result is reversed: the firm's profit decreases with ER.

It is useful to discuss the differences and similarities between Pecorino's results and ours in more detail. First, both ER and PI imply a stronger implicit negotiation power for the firm (the disagreement payoff of the firm is higher when two countries rather than one are concerned by the negotiation). This increases the firm's profits accrued in the foreign country in the same way under PI as under ER. Second, with PI the firm loses some of the profits accrued in the home country, also as under conditional ER. However, this reduction in profits is larger under conditional ER than under PI. In fact, it is so much larger, that the sum of profits in all countries falls under ER as opposed to the result with PI.

This difference is not due to the inherent disparity between PI and ER but to the different benchmarks considered in each paper. In Pecorino's, in the absence of PI the firm sets the monopoly price in the unregulated home country. By allowing PI, the price in the home country falls, and this causes a second order decrease on firm's profits, since the change in price starts from a profit maximizing price (the monopoly price).<sup>7</sup> We instead assume that the benchmark is one where the firm is negotiating the price in *both* countries. Thus, the benchmark prices considered are not profit maximizing, and the change in profits that is triggered by ER is *not* second order. It turns out that, with conditional ER, the fall in profits in the home country dominates. The idea is that, since ER is conditional, the firm loses the subsidy in both countries if negotiations in the foreign country fail, which weakens the firm's bargaining position.

To sum up, the differences between our results and Pecorino's reflect the context considered. Whilst Pecorino addresses the situation in the US, where pricing is

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<sup>6</sup> Actually, the benefits to the firm under unconditional ER are so high that the home country has no interest in adopting ER.

<sup>7</sup> This is noted by Pecorino, see page 707.



usually free of regulation, we concentrate on European countries where prices are usually negotiated.

As mentioned above, one can also draw some parallelisms between ER and MFN clauses. Indeed, a MFN clause forces the seller to charge the same price (the lowest price) to all the buyers, which is essentially what ER does. For example, Cooper and Fries (1991, CF henceforth) consider a monopolist who bargains with two buyers over a selling price, and they also use Nash bargaining. It is not surprising that some of their results are common to ours. To be more specific, under both policies, there is a country that decides on implementing the policy whereas the other country is affected by the policy. It is a common result under both policies that the affected country loses whereas the country that implements the policy wins with respect to the *status quo* (independent price negotiations). In contrast, ER and MFN clauses affect the firm in different ways. In CF the firm gains by the MFN whereas the firm loses with conditional ER. The reason is quite simple. CF assume that, for the MFN clause to be viable, the country that implements the policy and the firm must agree on the MFN clause. Hence, in CF the authors provide sufficient conditions ensuring that both this country and the firm are better off through the MFN clause. In sharp contrast, we assume that whether the ER policy is established or not is solely the country's choice. One may then wonder why the firm *never* benefits from conditional ER. The reason is that, with conditional ER, the firm is delisted from subsidization if negotiations fail in the affected country, which tends to reduce the firm's negotiation power *vis à vis* this country. If instead ER was unconditional, then the firm would benefit from ER, as in CF.

Unfortunately, a limitation to our study is that there is very scarce information about the details of existing ER policies. For example, we do not know whether these policies are conditional or unconditional, or whether their details are far more sophisticated than the ones we have described above. After all, an ER policy is an *ex-ante* commitment device and it could be made to depend on the complex flux of events it precedes. However, we believe that by focusing on the three examples that we have picked (unconditional ER, conditional ER with weak threats, and conditional ER with tough threats) we can gather the direction of the effects and demonstrate how important the design of the policy is.

The paper is organized as follows. A description of the European experience with ER is provided in Section 2. A two-country model with fixed-charge copayments is described in Section 3. Section 4 provides the solution to the benchmark case in which each country negotiates the price with the pharmaceutical firm, independently of the other country. Section 5 introduces the possibility that one country adopt a weak-threats ER policy, and analyzes its effects. We distinguish between unconditional ER (Subsection 5.1) and conditional ER (Subsection 5.2). Section 6 extends the analysis by considering transfers and section 7 extends the analysis to the tough-threats case. Section 8 concludes. All the proofs are in the appendix.

## **2. The European Experience**

Let us now overview the many instances of ER that one can find in Europe.<sup>8</sup> These cases motivate our assumptions, namely, that countries negotiate prices and that threats are weak. In other words, countries cannot threaten to not authorize drugs for sale if price negotiations fail.

### **Countries using ER and countries used as reference countries**

Many countries in Europe have implemented ER. However, not only the details differ from country to country, but are also changed often. For instance, in Denmark, foreign prices were used to determine the reimbursement price for drugs with same ATC-code, but this policy has been discontinued recently, and has been replaced by non-price controls. In Sweden, ER was discontinued in 2002. Hence, the situation is, to say the least, volatile and the examples given below are only valid as of the time of writing this section.

### **The ER formula**

As for inter-country differences, some administrations use the prices of other countries to construct an average reference price, whereas others take the minimum price. Among the first ones, some use a large list of referenced foreign countries.

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<sup>8</sup>There are countries outside Europe that also have implemented ER: Brazil (lowest price); Canada (median price); Japan, Korea, and Taiwan (average price).

Austria uses prices from Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Portugal, Spain, Sweden, and the UK. Finland adds, to the previous list, prices from Austria, Belgium, Ireland, and Norway. Also among countries using average prices, others use prices from just a handful of countries. This is what happens in the two examples presented in the introduction (the Netherlands and Switzerland). There are many other countries that take averages of country prices: Austria, Belgium, Italy, Lithuania take average prices minus 5% and Norway takes an average of the lowest 3 prices of the countries it considers.

As mentioned, some countries take the minimum instead of the average price. France uses the lowest price among Austria, Belgium, Denmark, Finland, Germany, Greece, Italy, the Netherlands, Portugal, Spain, Sweden, and the UK. Other countries using the same method are: Bulgaria, Croatia, Czech Republic, Estonia, Greece, Hungary, Latvia, Poland, Portugal, Romania, ex-Serbia-Montenegro, Slovakia, and Slovenia.

In summary, out of all European Countries, only UK, Sweden, Germany, and Denmark do not currently have an ER policy.

### **Weak versus tough threats**

Also importantly for our model, there are reasons to believe that most European experiences correspond to the weak threats scenario. The reason is simple. In Europe, authorization and price negotiation are separate processes carried out by independent agencies, based on different criteria, and with different time horizons. As Heuer et al. (2007) point out, “[W]ith the introduction of the European Medicines Evaluation Agency (EMA) in 1995, the EU Member States wanted to harmonize access to the pharmaceutical market” so that “[...] companies benefit from a larger market after authorization.” (p. 2). As for Switzerland, a non-EU state, Paris and Docteur (2007) report that “to be launched on the Swiss market, pharmaceutical products have to be approved by the Swissmedic [...]. The institute grants a marketing authorization if the product meets the requirements of quality, safety and effectiveness. The clinical assessment is based on data provided by the pharmaceutical company. This authorization is valid for 5 years.” In contrast, “The Federal Office of Public Health (OFSP) regulates both inclusion in the positive list and pricing of reimbursed pharmaceuticals.” On the other hand, outside Europe, Brazil and Canada are known to

threaten with not authorizing drug sales if negotiation fails or if the firm does not accept ER.

### **Empirical measures of the effects of ER**

Apart from the work by Windmeijer *et al.* (2006) mentioned in the introduction, there are several empirical studies that analyze the impact of price regulation. Unfortunately, more than exploring the effects of ER in isolation, most empirical studies aim to determining the effect of price controls in general.<sup>9</sup> An exception is Heuer et al (2007), who explore whether countries engaging in ER suffer from delays in the launch of pharmaceutical products. Although we do not address this phenomenon, we think that it is a good proxy for the importance of ER. Although the authors explore several explanatory variables (therapeutic value, cost-effectiveness, and so on), it is suggestive that the dummy variable for the presence of ER is significant at the 5% level.<sup>10</sup>

### **Relative market sizes**

An important result is that under conditional ER and under weak threats, the home country's preference for ER over independent negotiations diminishes as the foreign country's size grows, although it never disappears. In terms of the European experience, recall that the Netherlands uses an average of the prices in Belgium, France, Germany, and UK. If we divide pharmaceutical sales in the Netherlands in 2001 by pharmaceutical sales in each of these countries,<sup>11</sup> we obtain, respectively, 1.20, 0.18, 0.16, and 0.25. If we take the unweighted average of these numbers we obtain 0.45. If we performed the same calculation assuming that Germany was to use the same list of countries as benchmarks (adding the Netherlands and taking away

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<sup>9</sup> On the effects of regulation on price see Danzon and Chao (2000a, 2000b) and Cabrales and Jimenez (2007). On the effects of regulation and price differentials on launch delays see Danzon, Wang and Wang (2005) and Kyle (2007).

<sup>10</sup> More specifically, they show that, all else equal, if a country abolished the use of ER then the chance of launch within eight months would rise by 50.9%.

<sup>11</sup> Source: OECD HEALTH DATA 2007, July 07.

Germany), we would obtain 4.09. The fact that Germany does not engage in ER while the Netherlands does is not incompatible with our result.<sup>12</sup>

### 3. The Model

The players in this game are a pharmaceutical firm and the health authorities of two countries, H (home country) and F (foreign country). We refer to these players as the firm and the agencies. The firm sells a drug in both countries. It holds a patent for the drug in both countries and produces at no variable cost.<sup>13</sup>

Both agencies operate a positive list of reimbursed pharmaceuticals. If the drug is listed for reimbursement in country  $i$ , patients pay a fixed and exogenous copayment  $C_i$ , as long as price is above copayment. If the price is below the copayment we assume that the out-of-pocket payment  $Z_i$ ,  $i = F, H$ , is the price itself (no taxes). Formally,

$$Z_i = \text{Min}\{C_i, P_i\}, i = F, H.$$

The difference between the price and the copayment  $P_i - C_i$ , if positive, is reimbursed by the agency to the firm. If the drug is not listed for reimbursement then the patients pay the full price of the drug,  $P_i$ .

We assume that aggregate demand in country F is given by  $D(Z_F)$ , with  $D'(Z_F) < 0$ ,  $D''(Z_F) \leq 0$ . Note that by assuming that copayments are fixed, demand is independent of the price as long as the price is above the copayment. Country H is a  $K$ -replica of country F, with  $K > 0$  but not necessarily larger than one. We say that country H has size  $K$  while country F has size 1. Aggregate demand in country H is  $KD(Z_H)$ . We denote by  $P^M$  the monopoly price. In other words,  $P^M$  maximizes  $PD(P)$ . Notice that  $P^M$  is the same for both countries (and therefore independent of country size) due to two assumptions: zero variable costs (and in general due to

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<sup>12</sup> We can repeat a similar exercise using Gross Domestic Product at current prices in the 2nd quarter of 2006 (source: Eurostat), which is the most recent quarter for which we have a complete set of data. We obtain 0.63 (instead of 0.45) and 3.58 (instead of 4.09).

<sup>13</sup> The assumption that variable costs are negligible can be sustained empirically. Moreover, our analysis can be extended to situations with constant returns to scale. Having a positive marginal cost would only involve more complicated calculations, while in essence the results would be the same.

constant returns to scale gross of sunk costs), and country H being a  $K$ -replica of country F.

The following assumption reflects another asymmetry between the two countries.

**Assumption 1.** *If the drug is listed for reimbursement in both countries, patients pay less in country F than in country H, and they pay less than the monopoly price,  $P^M$ , in both countries. In other words,  $C_F < C_H < P^M$ .*

As we will see, H would never implement ER if  $C_F > C_H$ . If  $C_i > P^M$  for some country  $i$ , the drug subsidization system would vanish in that country.

Notice that F and H have different aggregate demands for two reasons. One is country size. The other is that, if country prices are larger than copayments, even if an individual in F has the same demand function as another in H and even if factory prices are the same in the two countries, the latter individual will demand less due to the higher copayment.

The pharmaceutical firm aims at maximizing its joint profit from both countries, with  $P_F D(Z_F)$  being profit in country F and  $P_H K D(Z_H)$  being profit in country H.

We assume that, in each country  $i$ , copayments are exogenously set beforehand by some outside player (say the Government or the Parliament of this country). Hence we do not aim at studying what the optimal copayment  $C_i$  should be. This depends on the outside players' preferences, whether the firm is owned by nationals or foreigners, equity and insurance considerations, consumption externalities, etc. The agency only bargains for low prices with firms in return for reimbursement rights. We believe this encompasses most real world cases.<sup>14</sup>

We assume that the agency is given the following mandate by the outside player: She should negotiate prices with the firm in order to maximize net consumer surplus minus the public costs of provision. Hence, the agency's objective function does not

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<sup>14</sup> Some countries rely on the so-called "tiered pricing" whereby lower prices result in the drug enjoying a higher subsidy. Our model amounts to a very simple tiered pricing mechanism. As it will be explained below, negotiation failure results in the drug not being listed for subsidization. Hence, only two tiers are present: a subsidy  $P - C_i$  or no subsidy at all.

include the profits of the firm. We believe this assumption also to be in accordance with reality, especially in countries with no pharmaceutical industry. A motivation might be that the outside player finds it beneficial to delegate the bargaining over price to a more aggressive negotiator.

Now, in a market of size  $K_i$ , with  $K_i = \{1, K\}$ , we define the net consumer surplus as:

$$K_i CS(Z_i) = K_i \left[ \int_0^{D(Z_i)} D^{-1}(q) dq - Z_i \cdot D(Z_i) \right].^{15}$$

The objective function of the agency of a country of size  $K_i$  is:

$$K_i CS(Z_i) - K_i (P_i - Z_i) \cdot D(Z_i).^{16}$$

We model the negotiation process as a Nash bargaining game. We assume that the scenario is one with weak-threats. Namely, we assume that if negotiations fail in a country, the drug is not listed for reimbursement but the firm is allowed to market the product in that country. Of course, the firm will do so at the monopoly price,  $P^M$ . If the drug is not listed for reimbursement, there are no public expenses associated with subsidizing the drug and the objective function of the government reduces to  $K_i CS(P^M)$ , the value of the net consumer surplus at the monopoly price.

The following lemma will be useful later on. Consider the following function:  $W(P) = PD(P) + CS(P)$ . This function reflects the sum of (*per capita*) consumer and producer surplus in the absence of subsidy. Then:

**Lemma 1.** *The function  $W$  is concave and attains a maximum at  $P = 0$ .*

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<sup>15</sup> We consider the consumer surplus as a measure of health benefits as it is linked to the willingness to pay for the drug.

<sup>16</sup> Notice that, if  $P_i < C_i$  then  $Z_i = P_i$  and the objective function becomes  $K_i CS(P_i)$ . Notice also that, if  $P_i > C_i$  then  $Z_i = C_i$  and the objective function of the agency is decreasing in  $C_i$ . Although, as explained above, we take copayments as exogenously set beforehand, it is useful to understand why this is so. Suppose that one increases the copayment so that demand is reduced by one unit. This has a negative effect on gross consumer surplus equal to the original copayment, as the unit that is no longer sold was enjoyed by the marginal consumer. However, it also has a positive effect, as total expenditures (consumer plus government's) are reduced by the price. Since our premise was that copayment was below price, the assumed objective function increases. In consequence, if the agency was in charge of setting copayments, drug consumption would not be subsidized. However, also as explained above, the outside player's preferences may be quite different from those of the agency.

This lemma is very intuitive. Since marginal cost is assumed to be zero, the price that would maximize the sum of consumer and producer surplus is also zero.

Finally, the agencies of both countries have the same bargaining power, denoted by  $\beta$ .

The bargaining power of the firm in either country is  $1 - \beta$ .

Throughout the text we denote  $D^M = D(P^M)$ ,  $CS^M = CS(P^M)$  and  $\pi^M = P^M D^M$ .

We also denote  $D_i = D(C_i)$ ,  $D'_i = D'(C_i)$ ,  $CS_i = CS(C_i)$  and  $CS'_i = CS'(C_i)$  for  $i = F, H$ .

#### 4. Independent Price Negotiations

Here we present our main benchmark case in which each country carries a price negotiation with the pharmaceutical firm, independently from the other country, and in the scenario with weak threats.<sup>17</sup> Therefore,  $K_i \cdot CS^M$  and  $K_i \pi^M$  constitute the disagreement payoffs of the agency and the firm, respectively.

The Nash bargaining problem for a country  $i$  of size  $K_i = \{1, K\}$  is:

$$\begin{aligned}
 & \text{Maximize} \\
 & \quad p_i \\
 & NB_{li} = \beta \ln \{ K_i [CS(Z_i) - (P_i - Z_i)D(Z_i) - CS^M] \} + (1 - \beta) \ln \{ K_i [P_i D(Z_i) - \pi^M] \} \\
 & \quad = \ln[K_i] + \beta \ln[CS(Z_i) - (P_i - Z_i)D(Z_i) - CS^M] + (1 - \beta) \ln[P_i D(Z_i) - \pi^M] \\
 & \text{subject to: } Z_i = \text{Min}\{C_i, P_i\} \tag{1}
 \end{aligned}$$

It is worth noting that in the bargaining problem of any country, we assume that the agency places no value on the consumer surplus or the public expenses of the other country. Note also that the size of the country,  $K_i$ , only constitutes a level effect in this bargaining problem, and in consequence will not affect the final price. By solving (1) we obtain the following lemma.

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<sup>17</sup> This analysis heavily draws from Jelovac (2003).



**Lemma 2.** *When both countries independently negotiate the price with the firm, then*

*(i) the resulting price in each country  $i$ ,  $i = F, H$  is:*

$$P_i^* = (1 - \beta)C_i + (1 - \beta)\frac{CS_i - CS^M}{D_i} + \beta\frac{\pi^M}{D_i}, \quad (2)$$

*(ii) This price is increasing in the level of copayment,  $C_i$  and decreasing in  $\beta$ , and*

*(iii)  $P_i^* > C_i$  for all  $i = F, H$ .*

The profits per capita in the bargaining solution in country  $i$  are:

$$\pi_i^* = P_i^* D_i = (1 - \beta)C_i D_i + (1 - \beta)[CS_i - CS^M] + \beta\pi^M$$

Note that these profits decrease in  $C_i$ , since:  $\partial \pi_i^* / \partial C_i = (1 - \beta)C_i D'_i < 0$ . Since  $C_F < C_H$  by Assumption 1, profits per capita are larger in country F.

Note that Part (i) of Lemma 2 implies the following equality:

$$(1 - \beta)[CS_i - CS^M - (P_i^* - C_i)D_i] = \beta[P_i^* D_i - \pi^M]. \quad (3)$$

Equation (3) illustrates that the surplus generated by the negotiation above the disagreement point is split between the country and the firm in the proportion  $\beta$  to  $1 - \beta$ , as usual in this type of problem.

In the bargaining problem, the disagreement point does not depend on the copayment  $C_i$ . Hence, the effect of the copayment on the negotiated price is only due to its effect on the surplus generated by the negotiation above the disagreement point. Let  $S(C_i)$  denote this surplus, with:

$$S(C_i) = CS_i + C_i D_i - CS^M - \pi^M. \quad (4)$$

Note that  $S(C_i)$  is decreasing in  $C_i$ :  $S'(C_i) = CS'_i + D_i + C_i D'_i = C_i D'_i < 0$ .

As the copayment increases, there is less to be split between the two parties and the negotiated solution converges to the monopoly outcome. The public costs of the subsidy decrease, and the agency can afford higher negotiated prices. At the same time, as the copayment increases, there is less for the firm to gain by negotiating and hence it requires a larger price. This explains Lemma 2. The next is a direct corollary.

**Corollary 3.** *For any  $K_i$  and with independent negotiations, the negotiated price in the country with a large copayment exceeds the negotiated price in the country with a small copayment:  $P_F^* < P_H^*$ .*

Therefore, we focus on the situation where the foreign country F is the reference country for the home country H.

## 5. The types of external referencing in the weak-threats scenario

In this section we consider the effects of an ER policy by H based on the price of country F. Our aim is to explain how H's ER affects the bargaining outcome in country F and to investigate whether it is in the interest of H to implement this policy. As explained in the introduction, an ER policy may take many different forms. In particular we must settle first how the price cap is defined. Is it any price in country F? Or is it the price in F as long as it results from successful negotiations? In the first case we say that the ER policy is *unconditional*, in the second case we say that the ER policy is *conditional*. If ER is conditional, we must specify what happens in the case of failed negotiations in F. As we are under the weak-threat scenario, we assume that if negotiations in country F fail, H ceases to reimburse the drug but still allows the firm to sell the drug at a full price chosen by the firm. Similarly, we assume that, if the firm decides not to respect the ER policy and sells the drug in country H at a price higher than the price cap, H ceases to reimburse the drug but still allows the firm to sell the drug at any price chosen by the firm.

The following table summarizes the types of ER that we analyze by showing, for each type, both the price paid by patients and the price received by the firm. It also describes the tough threat case, anticipating one of the extensions at the end of the paper.

**Table 1: The types of ER by agency H**

(patients' price, firm's price)	Unconditional ER with weak threats	Conditional ER with weak threats	ER with tough threats
Negotiations in F succeed; Firm accepts ER	$(C_F, P_F)$ in F $(C_H, P_F)$ in H		
Negotiations in F succeed; Firm rejects ER	$(C_F, P_F)$ in F $(P_H, P_H)$ in H		$(C_F, P_F)$ in F No sales in H
Negotiations in F fail; Firm accepts ER, if proposed	Product delisted in F only: $(P_F, P_F)$ in F $(C_H, P_F)$ in H	ER not proposed, product delisted in both countries : $(P_F, P_F)$ in F $(P_H, P_H)$ in H	No sales in either country
Negotiations in F fail; Firm rejects ER, if proposed	Product delisted in both countries: $(P_F, P_F)$ in F $(P_H, P_H)$ in H		

### 5.1 The effects of an unconditional ER policy

An unconditional ER policy requires the least information on the part of H. It is the only feasible policy if H is unable to verify whether the negotiation in F has been successful (or, equivalently, whether the drug is on F's positive list). In this case, if negotiations fail in country F, the firm is allowed to set a price  $P$  that maximizes  $P \cdot (\text{Max}\{D(P), 0\} + KD_B)$ . Note that this problem is unbounded, as the demand in country H is fixed. Hence, there is no surplus associated to the bargaining problem. In consequence, negotiations fail.<sup>18</sup> This illustrates, in a very extreme way, what is the problem with ER: It increases the disagreement payoff of the firm as compared to the disagreement payoff under independent negotiations ( $\pi^M$ ). In this case the increase is in fact unbounded.

To sum up, an unconditional price cap with fixed copayments results in a very adverse outcome for both the home and foreign country. In fact, this negative result motivates our research, as it is telling us that ER must have more to it than the mere "copying" of other countries' prices. Either more sophisticated policies should be in place (normative approach) or *are* in place despite not being actually observed because negotiations always succeed (positive approach). For this reason we turn our attention to conditional ER.

<sup>18</sup> If an exogenous bound exists on the payments that country H can make, then we have to qualify our previous statement on negotiation failure. It only holds if the exogenous bound is large enough. If it is not, we would run into some convoluted casuistics that lie beyond the point we want to make, namely, the extreme adverse effects of an unconditional ER on bargaining.

## 5.2 The effects of a conditional ER policy

If the negotiations in country F fail, the firm sells the drug with no subsidy in both countries. The disagreement payoffs of F's agency and the firm become, respectively,  $CS^M$  and  $(1+K)\pi^M$ . By backward induction, assume that  $P$  has been set in country F after successful negotiations. Then ER in H implies that the price offer made by the agency in H to the firm is  $P$ . This offer is accepted by the firm if and only if

$$P D(\text{Min}\{P, C_H\}) \geq \Pi^M.$$

Otherwise, the firm prefers to reject ER even at the cost of selling an unsubsidized drug in H. This restriction leads to the following lemma.

**Lemma 4.** *To be acceptable to the firm in H,  $P$  must be strictly larger than  $C_H$ .*

Once  $P > C_H$ , we know that  $D(\text{Min}\{P, C_H\}) = D(C_H) = D_H$ . Let us therefore define  $P^{MIN} = \Pi^M / D_H$  as the minimum acceptable price by the firm. The next lemma further characterizes this price.

**Lemma 5.**  $C_H < P^{MIN} < P^M$ .

As a consequence of Lemma 5, three separate intervals for  $P$  must be considered when F negotiates with the agency, since the formulae for negotiation payoffs are different in each interval. Namely,

- (i)  $P < C_F < P^{MIN}$ , where  $P$  is rejected by the firm in country H so consumers in H pay  $P^M$  while consumers in F pay  $P$ ; <sup>19</sup>
- (ii)  $C_F \leq P \leq P^{MIN}$ , where  $P$  is still rejected by the firm so consumers in H pay  $P^M$  while consumers in F pay  $C_F$ ;
- (iii)  $C_H < P^{MIN} \leq P$ , where  $P$  is accepted by the firm in country H and consumers in F pay  $C_F$  while consumers in H pay  $C_H$ .

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<sup>19</sup> We must consider  $P < C_F$  because part (iii) of Lemma 2 was derived under independent price negotiations, so the lemma does not directly apply once B engages in ER.

We now provide sufficient conditions ensuring that the Nash bargaining solution (hereafter NBS) in F yields  $P \geq P^{MIN}$ . We do this in two lemmas.

**Lemma 6.** *The NBS solution in F cannot yield  $P < C_F$ .*

**Lemma 7.** *There exists a function  $\tilde{\beta} = \tilde{\beta}(C_F, C_H)$  such that, for all  $\beta < \tilde{\beta}(C_F, C_H)$ , if we restrict  $P$  to be in  $[C_F, P^{MIN}]$  then the NBS yields  $P = P^{MIN}$ . The function  $\tilde{\beta}(C_F, C_H)$  is smaller than 1 and is decreasing in  $C_H$ .*

Let us explain the condition  $\beta < \tilde{\beta}(C_F, C_H)$ . This condition guarantees that the Nash bargaining function reaches a maximum at  $P^{MIN}$  if we restrict attention to  $P \leq P^{MIN}$ . This allows us to also restrict attention to  $P \geq P^{MIN}$  when solving the Nash bargaining problem, which greatly simplifies the analysis. If  $\beta$  was instead very large, then agency F's negotiation power would be so high that the negotiated price in A might fall below  $P^{MIN}$  and in this case the firm would reject ER. Notice that  $\beta < \tilde{\beta}(C_F, C_H)$  imposes some restrictions on the combination of parameters  $(\beta, C_F, C_H)$ , and that it is independent on  $K$ .<sup>20</sup> Finally, notice that by Lemma 4, we know that the resulting price  $P$  is strictly above  $C_H$ .

The Nash bargaining solution in country F is therefore the solution to the following program:

$$\begin{aligned} & \text{Maximize } \{P \geq P^{MIN}\} \\ & \beta \ln\{CS_F - (P - C_F)D_F - CS^M\} + (1 - \beta) \ln\{P(D_F + KD_F) - (1 + K)\pi^M\}. \end{aligned} \quad (5)$$

By solving (5) we obtain the following lemma.

**Lemma 8.** *If  $\beta < \tilde{\beta}(C_F, C_H)$ , when the conditional ER is adopted in country H, the negotiated price in country F is:*

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<sup>20</sup> We provide a numerical example at the end of this section.

$$P^{WC} = (1 - \beta)C_F + (1 - \beta)\frac{CS_F - CS^M}{D_F} + \beta\frac{(1 + K)\pi^M}{D_F + KD_H}, \quad (6)$$

which is strictly greater than  $P^{MIN}$  and is increasing in  $C_F$ ,  $C_H$  and  $K$ .

Lemma 8 allows us to write the following equality:

$$\begin{aligned} & (1 - \beta)\frac{D_F + KD_H}{D_F}\{CS_F - (P^{WC} - C_F)D_F - CS^M\} \\ &= \beta\{P^{WC}(D_F + KD_H) - (1 + K)\pi^M\} \end{aligned} \quad (7)$$

Equation 7 illustrates that the total surplus generated by the negotiation above the disagreement point is split between country F and the firm in the ratio:

$$\beta \text{ to } (1 - \beta)\frac{D_F + KD_H}{D_F} > (1 - \beta).$$

This shows that the implicit negotiation power of the firm is higher when country H engages in a conditional ER as compared to independent negotiations.

It is also interesting to analyze how changes in  $K$  affect the outcome of the negotiation in F on the face of ER. A raise in  $K$  affects the bargaining between F and the firm in two ways. First, the pie to be shared between both parties is larger. Hence there is an outwards shift in the frontier of the problem. Second, the firm has a stronger disagreement payoff whilst F's disagreement payoff remains the same. The next proposition tells us the outcome of these two effects.

**Proposition 9.** *Suppose that Assumption 1 holds and that  $\beta < \tilde{\beta}(C_F, C_H)$ . Then:*

- (i)  $P^{WC} - P_F^* > 0$  and this difference increases in  $K$ .
- (ii)  $P^{WC} - P_H^* < 0$ . This difference decreases in  $K$  and converges to an asymptote as  $K$  tends to infinity. This asymptote decreases in the difference  $C_H - C_F$ .

*Therefore, the difference between  $P^{WC}$  and  $P_H^*$  decreases monotonically as  $C_F$  tends to  $C_H$ .*

Proposition 9 is illustrated in Figure 1. It implies that H prefers to commit to a conditional ER policy rather than to engage in independent price negotiations with the firm. It also implies that this preference diminishes as the size of country H increases and as copayments become more homogeneous, but it is always positive. However, as a direct result of the adoption of ER in country H, the price negotiated in country F raises. This is explained by the change in the differences between failure and success payoffs of F and the firm. Moreover, as  $K$  increases the negotiated price in country F raises, but never to be so high that H loses out by choosing the ER policy rather than independently negotiating with the firm. Public expenses as well as the firm's profit in country H are lower. The opposite holds in country F.

[FIGURE 1 AROUND HERE]

Notice that consumers in either country are not affected by the ER policy since they pay a fixed copayment. The next proposition states that the total profits of the firm decrease because of the adoption of such an ER policy.

**Proposition 10.** *Under Assumptions 1 and  $\beta < \tilde{\beta}(C_F, C_H)$ , the total profits of the firm are lower when country H engages in ER, that is,*

$$P^{WC}(D_F + KD_H) < P_F^* D_F + P_H^* K D_H .$$

Consequently, the sum of public expenses in both countries also decreases, implying that the decrease in H's expenses compensates for the extra expenses in country F. This means that if country H wanted to fully compensate F for her “free riding”, she could do so and still achieve higher welfare than under independent negotiations.

#### *Numerical example*

We now present a numerical example to illustrate that the condition  $\beta < \tilde{\beta}(C_F, C_H)$  is not too restrictive and that it leaves enough room for ER to apply under a large set of parameter configurations. Let  $D(P) = 10 - P$ , so that  $P^M = 5$ . The following figure

plots  $\tilde{\beta}(C_F, C_H)$  for different values of  $C_F : \{0, 1, 2, 3, 4\} < P^M = 5$ . For each value of  $C_F$ , any point  $(C_H, \beta)$  lying below the corresponding curve is admissible.

[FIGURE 2 AROUND HERE]

## 6. Extension to transfers from the firm to the foreign country

We analyze here the possibility that the firm is able to make transfers to the agency in the foreign country in exchange for higher prices. We distinguish between the case where these transfers are not observable by country H and the case where they are observable.

In the first case, the situation is equivalent to one of unconditional ER: the firm is able to induce a large price in both countries. The only difference with the unconditional ER situation is that the foreign country is now not forced to delist the pharmaceutical drug.

In the second case, let us assume that, H delists the drug if a transfer is observed from the firm to country F. In this case the negotiations in F will be based on both the price  $P$  and the transfer  $T$ . The Nash Bargaining Problem becomes:

$$\text{Maximize}_{\{P, T > 0\}}$$

$$\beta \ln \{CS_F - (P - C_F)D_F + T - CS^M\} + (1 - \beta) \ln \{PD_F - T + K\pi^M - (1 + K)\pi^M\}$$

By letting  $\tau = PD_F - T$  and by canceling terms, this expression is equivalent to:

$$\text{Maximize}_{\{\tau > \Pi^M\}}$$

$$\beta \ln \{CS_F - \tau + C_F D_F - CS^M\} + (1 - \beta) \ln \{\tau - \pi^M\}.$$

It is easy to see that this problem is the same as the independent negotiation problem (1) for country F: choosing  $P$  in problem (1) (with  $K_i = 1$  and  $C_i = C_F$ ) is tantamount to choosing  $\tau$  here, since both  $D_F$  and  $T$  are constants. Hence, by accepting transfers, the agency in F is able to revert to an independent negotiations process. By part (i) of



Proposition 9, F prefers this to the ER outcome. Yet, the firm does not find it beneficial to engage in such transfers. First, using transfers decreases the firm's profit in country F up to the value obtained with an independent negotiation, which is lower than that under ER (also by Proposition 9). Second, using transfers implies that the drug will be delisted in country H, leading to profits  $\pi^M < \pi^{WC}$ . Therefore, no transfers should be observed.

## 7. Extension to tough-threats

As explained in the introduction, our main motivation is to provide insights into the European markets, where price negotiations have no bearing on the drug authorization decision (i.e. only weak threats are feasible). However, it is interesting to see that our main results remain even when agencies in charge of price negotiation can also threaten with a ban on the drug. In this section we assume that agencies in countries F and H are able to make such tough threats.

That is, with independent negotiations if the negotiation in a country fails, this country's agency does not authorize the drug for sale. Similarly, if H implements a conditional ER policy, then if negotiations in country F fail, again H does not authorize the drug for sale. Notice that tough threats change the disagreement payoff of both the Nash bargaining problem under independent negotiations and the Nash bargaining problem in F when H engages in ER.

Unfortunately, solving the model with tough threats at the same level of generality as the model with weak threats is quite complex. To illustrate this note that with tough threats and independent negotiations the disagreement point is no longer  $(CS^M, \pi^M)$ , but  $(0,0)$ . This means that it is difficult to rule out situations where price is so low that it falls below the copayment. Hence the analysis needs to deal with the non-differentiability of the patients' payment function. In contrast, in the weak threats scenario one can use the fact that profits must be above  $\pi^M$  to avoid this non-differentiability.

In order to derive some explicit results, we restrict attention to the linear demand case. More precisely, for  $\alpha, \psi > 0$ , let demand be given by

$$D(Z) = (\alpha - Z)/\psi.$$

We also assume that  $C_F = 0$ . This obviously guarantees that the price resulting from any negotiation taking place in country F is above the copayment in that country. This drastically reduces the number of cases and comparisons that one must address. Of course, we still assume that  $0 = C_F < C_H < P^M = \alpha/2$ , in order to have an interesting problem.

These assumptions allow us to derive a sufficient condition ensuring that:

- i) The price resulting from the Nash bargaining problem with ER by H is above  $C_H$ .
- ii) The price resulting from the Nash bargaining problem when H conducts independent price negotiations with the firm is also above  $C_H$ .
- iii) Agency H is able to decrease prices using ER. Thus, the main result that we obtained under weak threats is maintained.
- iv) In contrast to the weak threats scenario, under tough threats Country F is unaffected by ER. In other words, the negotiated price in F is the same irrespective of whether H engages in ER or not.
- v) As a direct result of (iii) and (iv), overall firm's profits decrease with ER.

Let us formalize these results.

**Proposition 11** *There exists a function  $\bar{\beta} = \bar{\beta}(K, C_H)$  such that, for all*

*$\beta < \bar{\beta}(K, C_H)$ , we have that*

$$P_F^{IPN} = P^{ER} = \alpha \frac{(1-\beta)}{2} < (\alpha + C_H) \frac{(1-\beta)}{2} = P_H^{IPN}.$$

*The function  $\bar{\beta}(K, C_H)$  is decreasing in  $K$  and  $C_H$ . Total firm's profits are lower under ER.*

The intuition for Proposition 11 is similar to the one in the previous section. If health authorities' bargaining power was high, prices would tend to be low, which as

explained above, would require dealing with the fact that the consumer copayment function is non-differentiable at  $C_H$ .<sup>21</sup>

A feature of ER under tough threats is that the negotiated price becomes independent of  $K$ . Intuitively, when the threat point is a sales ban in both countries, the size of the home country ceases –trivially– to influence the threat point.

Finally, and as we did in subsection 5.2, we provide a numerical example that shows that the assumption  $\beta < \bar{\beta}(K, C_H)$  is not too restrictive. In Figure 3, we depict  $\bar{\beta}(K, C_H)$  as a function of H's country size  $K$  for  $C_H = 1, 2, 3, 4$  and  $\alpha = 10$  (so that  $C_H < P^M = 5$ ).

[FIGURE 3 AROUND HERE]

## 8. Conclusions

Using a model where two countries differ only in their population size and subsidization policies, our most general result is that a country has an incentive to engage in ER if its copayment levels are high as compared to the other country's. This preference dwindles as the relative size of the country engaging in ER increases. We have analyzed how ER affects the negotiations in the foreign country of reference, F, proving that the design of the policy makes a substantial difference. One of the reasons for these differences is the fact that changing the design of the ER policy results in changes in the disagreement point in F's bargaining problem. Instead, an ER policy always increases the surplus to be shared between F and the firm no matter its design. The idea is that the profits obtained by the firm in the home country, H, become part of the pie.

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<sup>21</sup> We must preclude prices from falling below  $C_H$  in both the Nash bargaining program in H under IPN and in the Nash bargaining program in F when H engages in ER. This requires two upper bounds on  $\bar{\beta}$ , one for each program. The more restrictive bound arises with ER. The reason for this is that, under ER, agency H free rides on the better bargaining position of F.

We have also examined which is the best policy for H. Clearly H should never adopt unconditional ER. That is, foreign prices should only be used as price caps if these drugs are included in the foreign positive list.

With tough threats the firm suffers a harsher punishment in the case that negotiations fail. We show that if all countries are able to make tough threats the main result with weak threats turns out to be robust: ER benefits the home country and harms the firm.

Finally, for the case of conditional ER with weak threats, we can provide a clear empirical prediction that hinges on the relative size of the home country. Perhaps surprisingly, it turns out that the relative size of the home country is irrelevant as to *the sign* of the advantage of ER over independent negotiations. It is always positive. Only the size of the advantage is affected. In other words, should ER have some external and fixed cost that we have not taken into account,<sup>22</sup> then ER would only be implemented if the size of the home country is not too large. In a nut shell, only small countries should be observed to engage in ER and/or ER should be based on large countries (or a large group of countries). Our analysis yields an analogous prediction if one substitutes “large country” by “small copayment country” and *vice versa*.

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<sup>22</sup> For instance, some political cost.

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## Appendix

### Proof of Lemma 1

Since  $CS'(P) = -D(P)$ , differentiating  $W$  yields  $PD'(P)$ . Differentiating once again yields  $D'(P) + PD''(P)$ , which is negative. By setting the first derivative to zero, we obtain  $P = 0$ .

### Proof of Lemma 2

*Part (i)*

We first prove that  $P < C_i$  is not feasible in the Nash Bargaining Problem in any country  $i = F, H$ :

Notice that  $P D(P) < \Pi^M \equiv P^M D(P^M)$ , since  $P < C_i < P^M$  and  $P^M$  maximizes  $P D(P)$ . Hence,  $P D(P)$  is below the disagreement payoff for the firm for any  $P < C_i$ . Therefore, we can restrict attention to  $P \geq C_i$  so that  $Z_i = \text{Min}\{C_i, P_i\} = C_i$ ,  $C_i\} = C_i$  can be substituted into (1), which yields

Maximize  
 $p_i$

$$NB_{li} = \ln[K_i] + \beta \ln[CS(C_i) - (P_i - C_i)D_i - CS^M] + (1 - \beta) \ln[P_i D_i - \pi^M] \quad (A1)$$

The first order condition associated to (A1) can be written as:

$$\left. \frac{\partial NB_{li}}{\partial P_i} \right|_{P_i^*} = -\beta \frac{D_i}{CS_i - (P_i^* - C_i)D_i - CS^M} + (1 - \beta) \frac{D_i}{P_i^* D_i - \pi^M} = 0.$$

Rearranging this expression, equation (2) in Lemma 2 is obtained. This is the solution to (A1) since (A1) is concave in  $P$ :

$$\frac{\partial^2 NB_{li}}{\partial P_i^2} = -\beta \left[ \frac{D_i}{CS_i - (P_i - C_i)D_i - CS^M} \right]^2 - (1 - \beta) \left[ \frac{D_i}{P_i D_i - \pi^M} \right]^2 < 0.$$

Part (ii)

To check that  $P_i^*$  is increasing in  $C_i$ , rewrite the first-order condition associated to (A1) as:

$$(1 - \beta)(CS_i - (P_i^* - C_i)D_i - CS^M) - \beta(P_i^* D_i - \pi^M) = 0.$$

Applying the implicit function theorem to this expression, we obtain:

$$\frac{\partial P_i^*}{\partial C_i} = - \frac{(1 - \beta)[CS_i' + D_i - (P_i^* - C_i)D_i'] - \beta P_i^* D_i'}{-(1 - \beta)D_i - \beta D_i} = - \frac{D_i'}{D_i} [P_i^* - (1 - \beta)C_i].$$

This is positive, since equation (2) implies  $P_i^* > (1 - \beta)C_i$ .

Part (iii)

To prove that  $P_i^*$  is decreasing in  $\beta$ , take the derivative of  $P_i^*$  with respect to  $\beta$ . Using (2), this yields:

$$\frac{\partial P_i^*}{\partial \beta} = -C_i - \frac{CS_i - CS^M}{D_i} + \frac{\pi^M}{D_i}.$$

This is negative if and only if  $\pi^M + CS^M < C_i D_i + CS_i$ . This is equivalent to  $W(P^M) < W(C_i)$ , which holds by Lemma 1 and  $C_i < P^M$ .

Part (iii)

We now prove that  $P_i^* > C_i$ ,  $\forall i = F, H$ . By definition,  $\pi^M > P \cdot D(P)$ ,  $\forall P \neq P^M$ .

Therefore,  $C_i < P^M \Rightarrow \frac{\pi^M}{D_i} > C_i$ . Moreover,  $C_i < P^M \Rightarrow CS_i > CS^M$ . Therefore,

$$P_i^* > C_i, \forall i = F, H.$$

### Proof of Corollary 3

By part (ii) of Lemma 2 and  $C_F < C_H$ .



**Proof of Lemma 4**

Suppose  $P \leq C_H$ . Then  $\text{Min}\{C_H, P\} = P$  and  $PD(\text{Min}\{C_H, P\}) = PD(P)$ . However, since  $P^M$  maximizes  $PD(P)$  and  $C_H < P^M$ , we have that

$$PD(\text{Min}\{C_H, P\}) = PD(P) < P^M D^M \equiv \Pi^M,$$

a contradiction.

**Proof of Lemma 5.**

On the one hand, since  $C_H < P^M$ , we have that  $D_H > D^M$  and we can write

$$P^M > P^M \frac{D^M}{D_H} \equiv \frac{\Pi^M}{D_H} \equiv P^{MIN}.$$

On the other hand, since  $P^M$  maximizes  $PD(P)$ , we have that  $P^M D^M > C_H D_H$ . This

implies that  $P^{MIN} \equiv \frac{\Pi^M}{D_H} > C_H$ .

**Proof of Lemma 6.**

By Lemma 4, a price  $P < C_F$  would be rejected by the firm in H. Therefore, if by contradiction this price solves the NBS in F, it would solve

$$\text{Max} \quad \beta \ln\{CS(P) - CS^M\} + (1 - \beta) \ln\{PD(P) + K\pi^M - (1 + K)\pi^M\}.$$

This is equivalent to maximize

$$\text{Max} \quad \beta \ln\{CS(P) - CS^M\} + (1 - \beta) \ln\{PD(P) - \pi^M\}.$$

Notice that  $PD(P) < \Pi^M \equiv P^M D^M$ , since  $P < C_F < P^M$  and  $P^M$  maximizes  $PD(P)$ , so  $PD(P)$  is below the disagreement payoff of the firm for any  $P < C_F$ , contradiction.

### Proof of Lemma 7

A first step is to show that  $\frac{\Pi^M}{D_F} < C_F + \frac{CS_F - CS^M}{D_F}$ . To see this, rewrite the expression to get  $\Pi^M + CS^M < C_F D_F + CS_F$ . This inequality holds, as shown in the proof of Lemma 2 (part (ii)). The second step is to find  $P$  that solves

$$\text{Max } \beta \ln\{CS_F - (P - C_F)D_F - CS^M\} + (1 - \beta) \ln\{PD_F + K\pi^M - (1 + K)\pi^M\}.$$

This is equivalent to  $\text{Max } \beta \ln\{CS_F - (P - C_F)D_F - CS^M\} + (1 - \beta) \ln\{PD_F - \pi^M\}$ , which is the Nash bargaining problem in F under independent price negotiations,  $NB_{IF}$ . We know that the solution is given by  $P_F^*$ , given in Lemma 2. In the proof of this lemma we showed that the objective function in the Nash bargaining problem under independent price negotiations is concave in  $P$ . Therefore, it suffices to show that there exists some parameter configuration under which  $P_F^* > P^{MIN}$ , so that the Nash bargaining program defined here reaches a maximum at  $P^{MIN}$  when restricting the negotiated price to  $C_F < P \leq P^{MIN}$ . Comparing  $P_F^*$  with  $P^{MIN}$ , we find that the inequality  $P_F^* > P^{MIN}$  holds when

$$\beta < \frac{C_F + \frac{CS_F - CS^M}{D_F} - \frac{\Pi^M}{D_H}}{C_F + \frac{CS_F - CS^M}{D_F} - \frac{\Pi^M}{D_F}} \equiv \tilde{\beta}(C_F, C_H).$$

Notice that  $\tilde{\beta}(C_F, C_H) = 1$  when  $C_F = C_H$ , and  $\tilde{\beta}(C_F, C_H)$  is decreasing in  $C_H$ . Therefore,  $\tilde{\beta}(C_F, C_H) < 1$  when  $C_F < C_H$ .

### Proof of Lemma 8

The first-order condition associated to the Nash bargaining program (5) can be written as:

$$\begin{aligned} \left. \frac{\partial NB_2}{\partial P} \right|_{P^{**}} &= -\beta \frac{D_F}{CS_F - (P^{WC} - C_F)D_F - CS^M} \\ &\quad + (1-\beta) \frac{D_F + KD_H}{P^{WC}(D_F + KD_H) - (1+K)\pi^M} = 0. \end{aligned}$$

Rearranging this expression, equation (6) in Lemma 8 is obtained. This is the solution to (5) since (5) is concave in  $P$ :

$$\frac{\partial^2 NB_2}{\partial P^2} = -\beta \left[ \frac{D_F}{CS_F - (P - C_F)D_F - CS^M} \right]^2 - (1-\beta) \left[ \frac{D_F + KD_H}{P(D_F + KD_H) - (1+K)\pi^M} \right]^2 < 0.$$

Since we already proved that the Nash bargaining function is concave for  $P \geq P^{MIN}$ , to show that  $P^{WC}$  is a global maximum it suffices to prove that (i)  $P^{WC} > P^{MIN}$  and (2) that the Nash bargaining function is continuous at  $P = P^{MIN}$ . Let us prove (i). From the proof of Lemma 7, we know that  $P_F^* > P^{MIN}$  when  $\beta < \tilde{\beta}(C_F, C_H)$ . Let us now prove that  $P^{WC} > P_F^*$ . Indeed, using Lemma 2 (for  $i = F$ ) and Lemma 8, we can write

$$P^{WC} = P_F^* + \beta K \pi^M \left[ \frac{D_F - D_H}{D_F(D_F + KD_H)} \right] > P_F^*.$$

Let us now prove (ii). This is by inspection by substituting  $P = P^{MIN}$  in  $NB_1$  and  $NB_2$ .

Differentiating  $P^{WC}$  with respect to  $C_F$  and  $C_H$ , we obtain, respectively:

$$\frac{\partial P^{WC}}{\partial C_F} = (1-\beta) \left[ 1 + \frac{CS'_F D_F - D'_F (CS_F - CS^M)}{(D_F)^2} \right] - \beta D'_F \frac{(1+K)\pi^M}{(D_F + KD_H)^2}.$$

Using the fact that  $CS'_F = -D'_F$  we can simplify the expression to:

$$\frac{\partial P^{WC}}{\partial C_F} = -D'_F \left[ (1-\beta) \frac{CS_F - CS^M}{(D_F)^2} + \beta \frac{(1+K)\pi^M}{(D_F + KD_H)^2} \right] > 0,$$

and

$$\frac{\partial P^{WC}}{\partial C_H} = -KD'_H \beta \frac{(1+K)\pi^M}{(D_F + KD_H)^2} > 0.$$

Finally note that:

$$\frac{\partial P^{WC}}{\partial K} = \frac{\beta \pi^M (D_F - D_H)}{(D_F + KD_H)^2} > 0.$$

### **Proof of Proposition 9**

*Part (i)*

In the proof of Lemma 8 we proved that  $P^{WC} > P_F^*$ . Notice that

$$\frac{\partial(P^{WC} - P_F^*)}{\partial K} = \beta \pi^M \left[ \frac{D_F - D_H}{D_F (D_F + KD_H)} \right] > 0.$$

*Part (ii)*

As  $K$  tends to infinity,  $P^{WC}$  tends to:

$$P_{\lim}^{WC} = (1 - \beta)C_F + (1 - \beta) \frac{CS_F - CS^M}{D_F} + \beta \frac{\pi^M}{D_H}.$$

To compare  $P_{\lim}^{WC}$  with  $P_H^*$  as defined in Lemma 2, it is enough to notice that the auxiliary function  $f(Z)$  is increasing in  $Z$ , where:

$$f(Z) = Z + \frac{CS(Z) - CS^M}{D(Z)}.$$

Using  $CS'(Z) = -D(Z)$  and assuming that  $Z < P^M$ , we have that:

$$f'(Z) = -\frac{D'(Z)[CS(Z) - CS^M]}{[D(Z)]^2} > 0.$$

This implies  $P_{\lim}^{WC} < P_H^*$ , since  $C_F < C_H$ . Given that  $P^{WC}$  is increasing in  $K$  (see Lemma 8),  $P^{WC} - P_H^* < 0$ ,  $\forall K$ .

The fact that  $f'(Z) > 0$  also implies that the difference  $R = P_H^* - P_{\lim}^{WC}$  decreases as  $C_F$  tends to  $C_H$ . Therefore, the difference between  $P^{WC}$  and  $P_H^*$  decreases monotonically as  $C_F$  tends to  $C_H$ .

### Proof of Proposition 10

Define  $\Delta(C_F, C_H, K) = P_F^* D_F + P_H^* K D_H - P^{WC} (D_F + K D_H)$ . We need to prove that  $\Delta(C_F, C_H, K) > 0$ . Suppose first that  $K = 0$ . In this case  $P_F^* = P^{WC}$  and therefore  $\Delta(C_F, C_H, 0) = (P_F^* - P^{WC}) D_F = 0$ . Hence it suffices to prove that  $\frac{\partial \Delta}{\partial K} > 0$ . That is, we need:

$$\frac{\partial \Delta}{\partial K} = P_H^* D_H - (D_F + K D_H) \frac{\partial P^{WC}}{\partial K} - P^{WC} D_H = (P_H^* - P^{WC}) D_H - (D_F + K D_H) \frac{\partial P^{WC}}{\partial K} > 0.$$

Substituting  $P^{WC}$  from Lemma 8,  $P_H^*$  from Lemma 2, and the formula of  $\frac{\partial P^{WC}}{\partial K}$  derived in the proof of Lemma 8 we obtain:

$$\frac{\partial \Delta}{\partial K} = [f(C_H) - f(C_F)](1 - \beta) D_H + \beta \pi^M \left[ 1 - \frac{(1 + K) D_H}{D_F + K D_H} - \frac{(D_F - D_H)}{D_F + K D_H} \right],$$

where  $f(Z)$  is as defined in the proof of Proposition 9. Notice that the second term in the last expression is zero. The expression in brackets in the first term is positive since  $f'(Z) > 0$  as shown in the proof of Proposition 9.

### Proof of Proposition 11

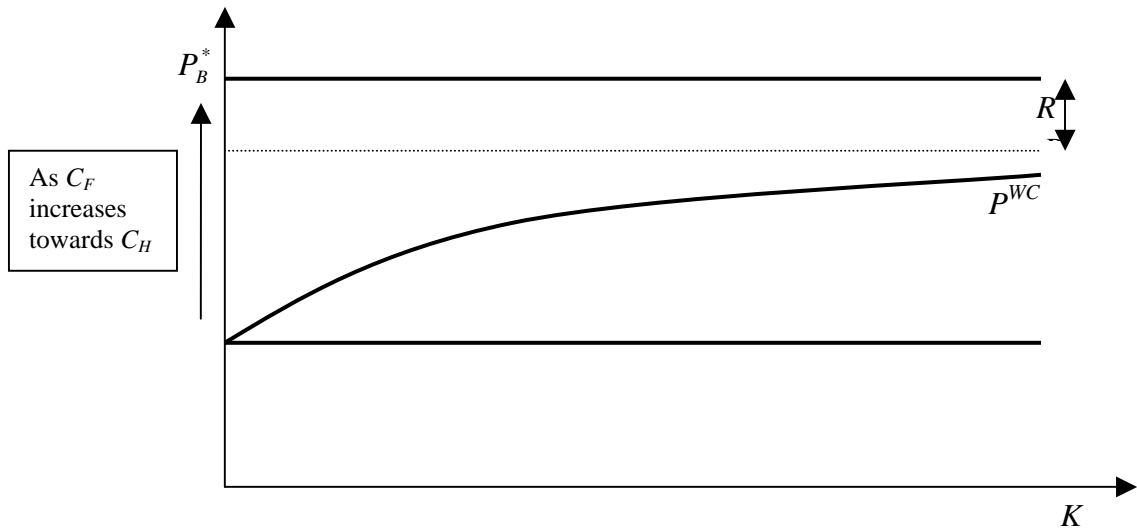
The proof of Proposition 11 is available upon request from the authors. It is similar to the proof of Propositions 9 and 10 and of the lemmas preceding those propositions. We limit ourselves to provide the exact formula of the function  $\bar{\beta}(K, C_H)$ . To ease

presentation, we introduce two auxiliary functions. Let  $\Gamma = K(\alpha - 2C_H)^2 + \alpha^2$ . By inspection,  $\Gamma$  is increasing in  $K$ . Since  $C_H < P^M = \alpha/2$ , we have that  $2C_H < \alpha$ . This implies that  $\Gamma$  is increasing in  $\alpha$  and decreasing in  $C_H$ . Then,

$$\bar{\beta}(K, C_H) = \frac{1 - \frac{2\alpha C_H}{\Gamma}}{1 + 2KC_H \frac{\alpha - C_H}{\Gamma}}.$$

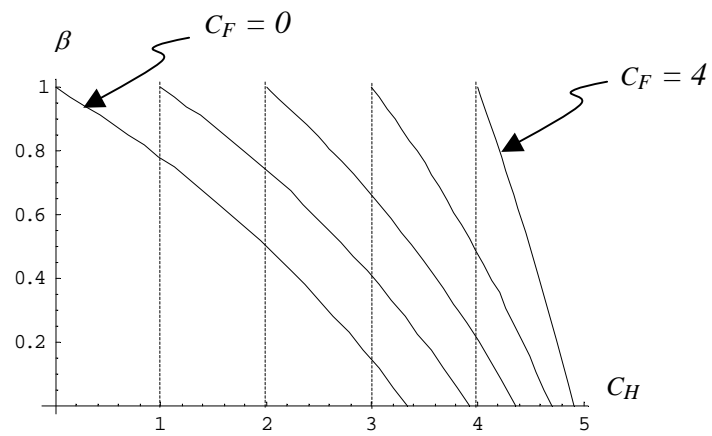
Notice that  $\bar{\beta}(K, C_H) < 1$ . One can also check that  $\bar{\beta}(K, C_H) > 0$  and that it is decreasing in  $K$  and  $C_H$ .

FIGURE 1



**Figure 1.** Comparing independent price negotiations to weak-threats conditional ER as country H's size ( $K$ ) increases relative to country F's. The value of  $R$  is derived in the Appendix (proof of Proposition 9). It decreases as  $C_F$  increases.

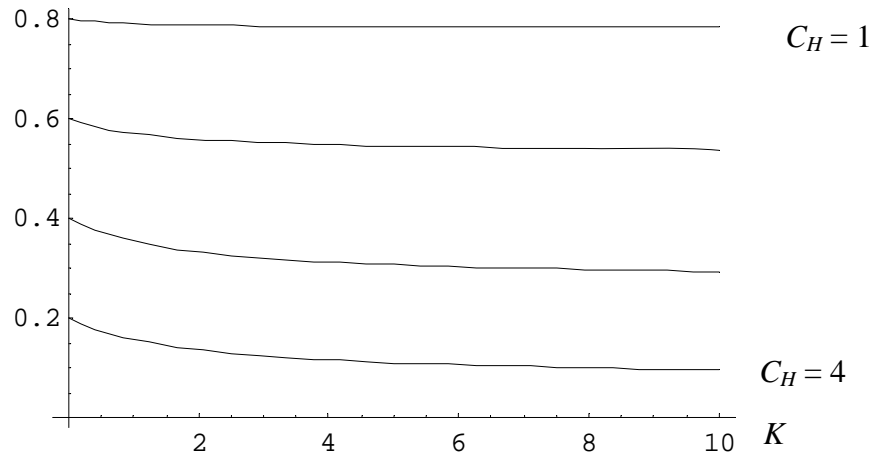
FIGURE 2



**Figure 2.** Admissible parameter configurations.



FIGURE 3



**Figure 3.** The maximum value for  $\beta$  as a function of  $K$  for different values of  $C_H$  and  $\alpha = 10$ .